The Ecology and Acoustic Behavior of Minke Whales in the Hawaiian and Pacific Islands: A Study to Assess the Distribution, Abundance, Acoustic Behaviors, and the Effects of Noise on a Visually Elusive, but Acoustically Active Species

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LONG-TERM GOAL & OBJECTIVES

The main objective of this joint project was to use vessel-based passive acoustic methods collecting data to estimate the density and abundance of minke whales at our study site. A second objective was to investigate minke whale acoustic behavior including an investigation of its sensitivity to noise. The third objective was to investigate the population structure of minke whales by measuring and comparing acoustic characteristics of boings recorded at our study area in Hawaii to other regions such as the Marianas Islands and Midway Island.

APPROACH

In reviewing the initial localizations obtained in the field for minke whale calls, we were concerned about the quality of our data as there were processed in real-time with little operator supervision. This can result in many uncertainties and errors which cannot be easily assessed during field operations. Therefore the acoustic data are being re-analyzed and quality controlled to calculate more precise perpendicular distances to the track-line from localizations. To be able to achieve this, a new software tool named "BOINGER" was developed at the University of St Andrews in Janik's research group.

		Form Approved OMB No. 0704-0188

Report Documentation Page

1. REPORT DATE **30 SEP 2011**	2. REPORT TYPE	3. DATES COVERED **00-00-2011 to 00-00-2011**
4. TITLE AND SUBTITLE **The Ecology and Acoustic Behavior of Minke Whales in the Hawaiian and Pacific Islands: A Study to Assess the Distribution, Abundance, Acoustic Behaviors, and the Effects of Noise on a Visually Elusive, but Acoustically Active Species**		5a. CONTRACT NUMBER
		5b. GRANT NUMBER
		5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER
		5e. TASK NUMBER
		5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **University of St Andrews,Scottish Oceans Institute,Sea Mammal Research Unit,St Andrews, KY16 8LB United Kingdom,**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S)
		11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**4**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

WORK COMPLETED & RESULTS

It was coded in Matlab and is an add-on to other acoustic localization software such as Pamguard (Gillespie et al. 2008) or Ishmael (Mellinger 2001). It provides additional analysis steps that allow better quality control and the possibility to combine separate whale locations to tracks. Boinger uses three analysis steps that allow to plot the locations of calling whales: (1) it determines time-of-arrival differences (TOADs) of sounds recorded on a linear array using cross correlation, (2) it plots the vessel track and the corresponding bearings to each acoustic event based on the TOADs and (3) it calculates and stores the locations of intersecting hyperbolas from different bearings in user-defined groups. Unlike other passive acoustic localization software, BOINGER allows to localize whales based on the bearings to different sounds in a calling sequence while the vessel is moving.
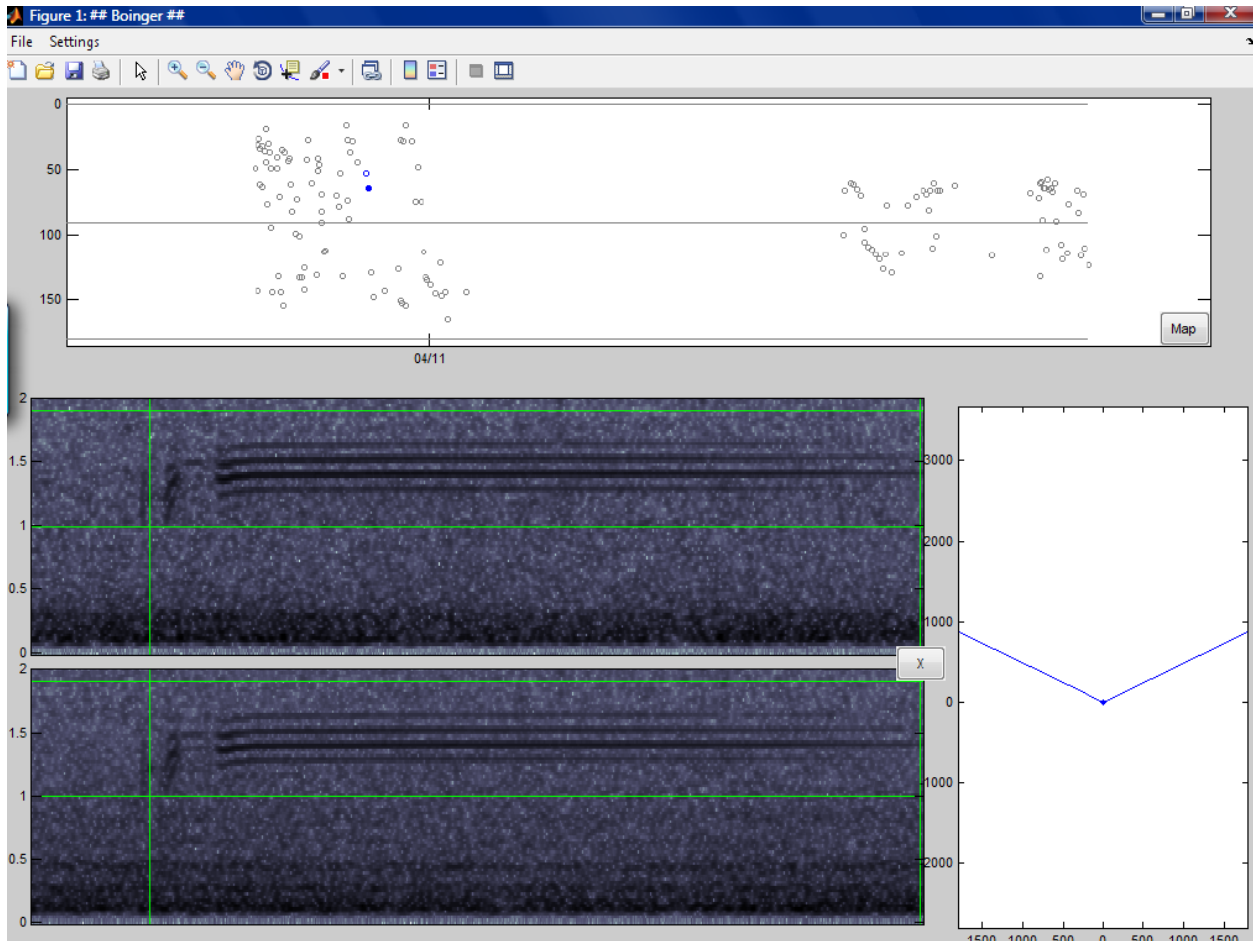

Fig. 1: BOINGER display showing bearing information from the database (upper panel), spectrograms of the signals on each of two channels (lower left panel), and a bearing display based on its own cross-correlation calculation (lower right panel). Green lines are moveable cursors that define the area used in the cross correlation.

The localization process is supervised by an operator and needs decisions about which signals, bearings, and locations are used. BOINGER requires an input database that holds information on the times of acoustic events (detections). It uses this data input to locate the acoustic event in a large sound file. In the first window, BOINGER displays the spectrograms of each channel of a selected detection, all bearing information provided by the database highlighting the bearing that corresponds to the signal selected (upper panel in Fig. 1), and the bearing display from its own cross-correlation calculation (panel on lower right in Fig. 1). An acoustic event can be selected by clicking on a detection in the upper panel. The program then loads the corresponding sound files into the spectrogram window. The operator can determine the time and frequency window for correlation by moving cursors displayed on the spectrograms. BOINGER determines the appropriate peak in the cross-correlation function by investigating the slope of the envelope of the cross-correlation function. The operator can inspect the cross-correlation function and adjust the selected peak if required. The new bearing information can then be stored if none is available in the database or overwrite any old bearing that has been adjusted. Symbols in the upper panel indicate whether bearings have been obtained from the database or were re-calculated in BOINGER.

Previous work by Martin and Norris in this project (see previous reports) has shown that individual whales can be identified by the peak frequency they use in their calls. BOINGER provides the option to display an averaged power spectrum of all signal channels calculated over the time and frequency range specified by the spectrogram cursors. It also indicates the peak frequency by a yellow line on the spectrum and allows the operator to store it.

In the next step, BOINGER plots the track of the vessel and all available bearings from it (Fig. 2, upper panel). Here, bearings can be inspected by the operator and manually marked as belonging to the same event. Once two or more intersecting bearings have been marked, BOINGER will calculate the location of the calling animal by averaging the geographic location of all intersection points. This is done separately for each side of the track to create two possible locations according to the left-right ambiguity of linear arrays. The distance and bearing of each location from the track line is then calculated and can be stored. In the lower panel of the same screen (Fig. 2 lower panel), BOINGER creates a plot of the peak frequencies of calls where they have been measured. If the operator selects a bearing by clicking on it, the corresponding frequency measurement will be highlighted, and vice versa. Since peak frequencies are individually distinctive (see above) this can help the operator to identify what bearings belong to the same animal. The operator can select several bearings and mark them as one localization event and also mark several locations and mark them as belonging to the same animal. The color of each bearing belonging to the same animal is then given the same color by BOINGER to make them stand out on the screen. For groups of locations, BOINGER connects them with a dotted line, indicating the assumed movement between calls for the selected animal. Such movement lines as well as single animal detections are then stored by BOINGER in a database.

IMPACT/APPLICATIONS

The BOINGER software has been developed to analyze the minke whale recordings obtained from the towed array in Norris project N00014-10-1-0429. It will create a database with individual locations and distances of animals from the track line. These data will be used for estimating density by the Thomas research group using modified line-transect methods with the "Distance" program. The resulting density estimate will be used to determine an average boing rate per animal for use in the DECAF/SECR density estimation effort. This will be achieved towards the end of the current no-cost-extension of this project.
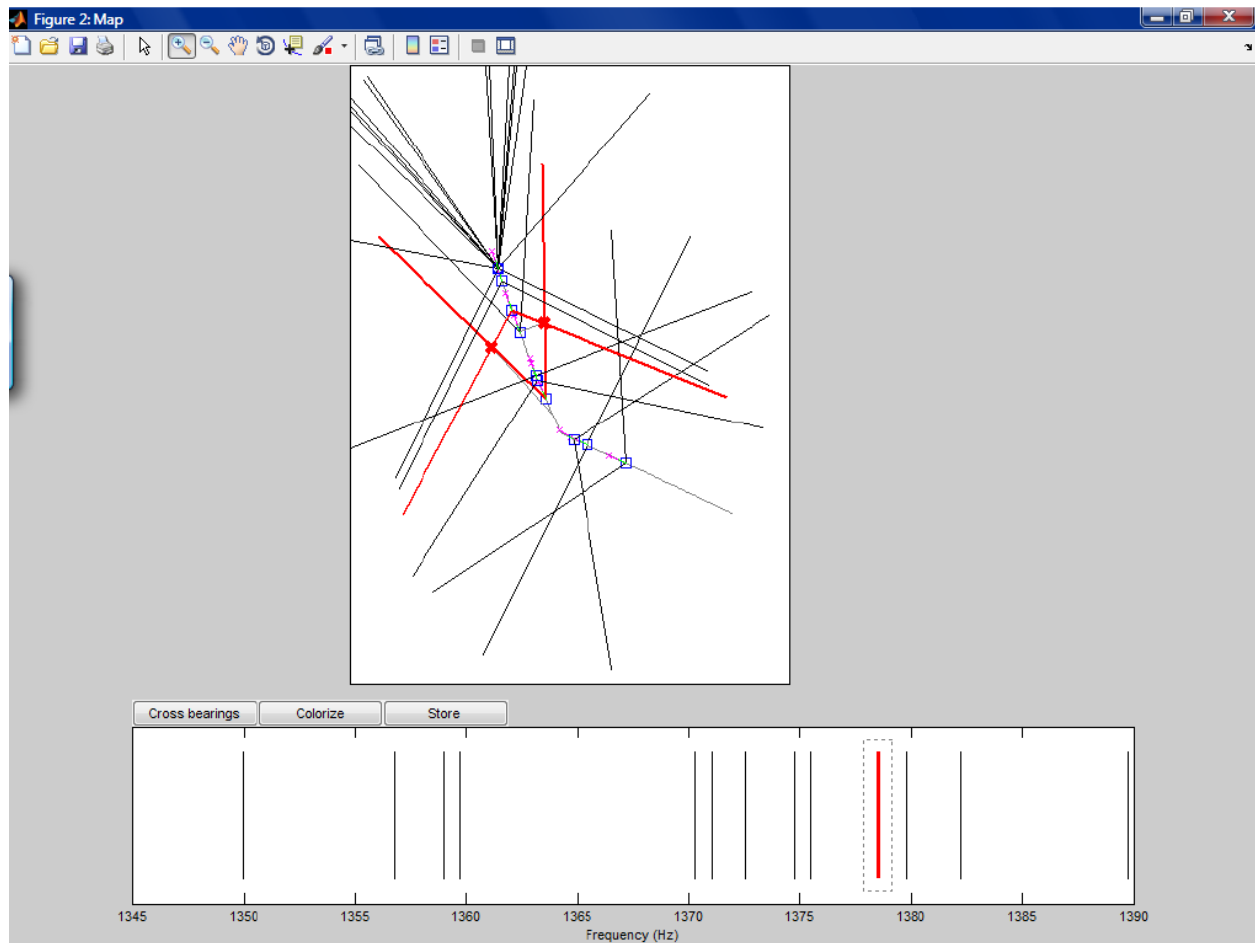
Figure 2. A map display (upper panel) and peak frequency display (lower panel) produced by BOINGER. In the upper display, the track line (line connecting blue squares) and all selected bearings formm the first stpe in the anlaysis are displayed. Bearings can be grouped to determine locations by storing points where hyperbolas intersect (red lines). The highlighted peak frequency in the lower panel corresonpds to the red bearing in the upper panel.

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